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# Evaluation of Military Field-Water Quality

## Volume 3. Opportunity Poisons

V. J. Ciccone and M.-B. Carmer

J. I. Daniels (Editor)

December 1987

Lawrence Livermore National Laboratory

Supported by
U.S. Army Medical Research and Development Command
Fort Detrick, Frederick, MD 21701-5012
Project Order 82PP2817
Project Officer: Dr. Stephen A. Schaub

Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

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UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

# REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

| | |
|---|---|
| 1a. REPORT SECURITY CLASSIFICATION: UNCLASSIFIED | 1b. RESTRICTIVE MARKINGS: ----- |
| 2a. SECURITY CLASSIFICATION AUTHORITY: ----- | 3. DISTRIBUTION/AVAILABILITY OF REPORT: Approved for public release; distribution unlimited |
| 2b. DECLASSIFICATION/DOWNGRADING SCHEDULE: ----- | |
| 4. PERFORMING ORGANIZATION REPORT NUMBER(S): UCRL-21008 Vol. 3 | 5. MONITORING ORGANIZATION REPORT NUMBER(S): ----- |
| 6a. NAME OF PERFORMING ORGANIZATION: Lawrence Livermore National Laboratory / 6b. OFFICE SYMBOL (If applicable) | 7a. NAME OF MONITORING ORGANIZATION: U.S. Army Biomedical Research and Development Laboratory |
| 6c. ADDRESS (City, State, and ZIP Code): Environmental Sciences Division, P.O. Box 5507 (L-453), Livermore, CA 94550-0617 | 7b. ADDRESS (City, State, and ZIP Code): ATTN: SGRD-UBZ-C, Fort Detrick (Bldg. 568), Frederick, MD 21701-5010 |
| 8a. NAME OF FUNDING/SPONSORING ORGANIZATION: U.S. Army Medical Research and Development Command / 8b. OFFICE SYMBOL (If applicable) | 9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER: Army Project Order 82PP2817 |
| 8c. ADDRESS (City, State, and ZIP Code): Fort Detrick, Frederick, MD 21701-5012 | 10. SOURCE OF FUNDING NUMBERS |

| PROGRAM ELEMENT NO. | PROJECT NO. 3M1- | TASK NO. | WORK UNIT ACCESSION NO. |
|---|---|---|---|
| 62787A | 62787A875 | AG | DA300881 |

11. TITLE (Include Security Classification): Evaluation of Military Field-Water Quality Volume 3. Opportunity Poisons

12. PERSONAL AUTHOR(S): V.J. Ciccone and M.-B. Carmer

| 13a. TYPE OF REPORT | 13b. TIME COVERED | 14. DATE OF REPORT (Year, Month, Day) | 15. PAGE COUNT |
|---|---|---|---|
| Final | FROM 8-83 TO 12-87 | December 1987 | 52 |

16. SUPPLEMENTARY NOTATION: -----

| 17. COSATI CODES | | |
|---|---|---|
| FIELD | GROUP | SUB-GROUP |
| 24 | 07 | |
| 06 | 11 | |

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number): Opportunity poisons, military, water, scenarios, reverse osmosis water purification unit (ROWPU).

19. ABSTRACT (Continue on reverse if necessary and identify by block number) The term "opportunity poison" refers to any substance that in military situations might be intentionally added to field water to deny its use; it implies that such contamination will be introduced as a spontaneous action, rather than as part of a preconceived plan. Thus, there are many different substances in military inventories and the civilian marketplace that because of their availability and toxic or organoleptic properties (e.g., taste, odor, or appearance) can be considered potential opportunity poisons for field water. To identify these substances and indicate their relative importance from a military perspective, we present a categorization matrix in which classes of compounds are ranked according to their military significance as potential opportunity poisons. The categorization matrix was assembled by considering (1) the probable availability from military or civilian sources, (2) the possible water-related health or aesthetic effects, and (3) the potential impacts on water-treatment equipment of the principal constituents of each class of compounds. On the basis of this
(continued on next page)

| | | |
|---|---|---|
| 20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS | 21. ABSTRACT SECURITY CLASSIFICATION: UNCLASSIFIED | |
| 22a. NAME OF RESPONSIBLE INDIVIDUAL: Mary Frances Bostian | 22b. TELEPHONE (Include Area Code): 301-663-7325 | 22c. OFFICE SYMBOL: SGRD-RMI-S |

DD Form 1473, JUN 86 Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

analysis, recommendations are made for U.S. military forces to meet the threat of opportunity poisons by instituting guidelines and training programs that will (1) alert field forces to situations likely to involve the use of opportunity poisons and (2) define appropriate procedures for dealing with such situations. Quantifying the effects of the most important opportunity poisons (e.g., petroleum products) on field-water treatment equipment, particularly the reverse osmosis water purification unit (ROWPU), also is advised so that contingency plans can be made for operating and maintaining the equipment in the presence of such opportunity poisons.

This report is the third volume of a nine-volume study entitled Evaluation of Military Field-Water Quality. Titles of the other volumes are as follows: Vol. 1, Executive Summary; Vol. 2, Chemical Constituents of Military Concern; Vol. 4, Criteria and Recommendations for Standards for Chemical Constituents of Military Concern; Vol. 5, Infectious Organisms of Military Concern Associated with Consumption: Assessment of Health Risks, and Recommendations for Establishing Related Standards; Vol. 6, Infectious Organisms of Military Concern Associated with Nonconsumptive Exposure: Assessment of Health Risks, and Recommendations for Establishing Related Standards; Vol. 7, Performance Evaluation of the 600-GPH Reverse Osmosis Water Purification Unit (ROWPU): Reverse Osmosis (RO) Components; Vol. 8, Performance of Mobile Water Purification Unit (MWPU) and Pretreatment Components of the 600-GPH Reverse Osmosis Water Purification Unit (ROWPU) and Consideration of Reverse Osmosis (RO) Bypass, Potable-Water Disinfection, and Water-Quality Analysis Techniques; Vol. 9, Data for Assessing Health Risks in Potential Theaters of Operation for U.S. Military Forces.

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# Evaluation of Military Field-Water Quality

## Volume 3. Opportunity Poisons

V. J. Ciccone* and M.-B. Carmer*

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Principal Investigators at Lawrence Livermore National Laboratory:
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# FOREWORD

This report is the third volume of a nine-volume study entitled Evaluation of Military Field-Water Quality. Titles of the other volumes are as follows: Vol. 1, Executive Summary; Vol. 2, Constituents of Military Concern from Natural and Anthropogenic Sources; Vol. 4, Health Criteria and Recommendations for Standards; Vol. 5, Infectious Organisms of Military Concern Associated with Consumption: Assessment of Health Risks, and Recommendations for Establishing Related Standards; Vol. 6, Infectious Organisms of Military Concern Associated with Nonconsumptive Exposure: Assessment of Health Risks, and Recommendations for Establishing Related Standards; Vol. 7, Performance Evaluation of the 600-GPH Reverse Osmosis Water Purification Unit (ROWPU): Reverse Osmosis (RO) Components; and Vol. 8, Performance of Mobile Water Purification Unit (MWPU) and Pretreatment Components of the 600-GPH Reverse Osmosis Water Purification Unit (ROWPU) and Consideration of Reverse Osmosis (RO) Bypass, Potable-Water Disinfection, and Water-Quality Analysis Techniques; Vol. 9, Data for Assessing Health Risks in Potential Theaters of Operation for U.S. Military Forces.

As indicated by the titles listed above, the nine volumes of this study contain a comprehensive assessment of the chemical, radiological, and biological constituents of field-water supplies that could pose health risks to military personnel as well as a detailed evaluation of the field-water-treatment capability of the U.S. Armed Forces. The scientific expertise for performing the analyses in this study came from the University of California Lawrence Livermore National Laboratory (LLNL) in Livermore, CA; the University of California campuses located in Berkeley (UCB) and Davis (UCD), CA; the University of Illinois campus in Champaign-Urbana, IL; and the consulting firms of IWG Corporation in San Diego, CA, and V.J. Ciccone & Associates (VJCA), Inc., in Woodbridge, VA. Additionally a Department of Defense (DoD) Multiservice Steering Group (MSG), consisting of both military and civilian representatives from the Armed Forces of the United States (Army, Navy, Air Force, and Marines), as well as representatives from the U.S. Department of Defense, and the U.S. Environmental Protection Agency provided guidance, and critical reviews to the researchers. The reports addressing chemical, radiological, and biological constituents of field-water supplies were also reviewed by scientists at Oak Ridge National Laboratory in Oak Ridge, TN, at the request of the U.S. Army. Furthermore, personnel at several research laboratories, military installations, and agencies of the U.S. Army and the other Armed Forces provided technical assistance and information to the researchers on topics related to field water and the U.S. military community.

# ACKNOWLEDGMENTS

The principal investigators at the Lawrence Livermore National Laboratory (LLNL), Drs. Jeffrey Daniels, David Layton, and Lynn Anspaugh, extend their gratitude and appreciation to all of the participants in this study for their cooperation, assistance, contributions and patience, especially to Dr. Stephen A. Schaub, the project officer for this monumental research effort, and to his military and civilian colleagues and staff at the U.S. Army Biomedical Research and Development Laboratory (USABRDL). A special thank you is extended to the editors, secretaries, and administrative personnel of the Environmental Sciences Division at LLNL, particularly to Ms. Barbara Fox, Ms. Yvonne Ricker, Ms. Penny Webster-Scholten, Mr. E.G. Snyder, Ms. Gretchen Gallegos, Ms. Angelina Fountain, Ms. Sherry Orman, Mr. David Marcus, Ms. Martha Maser, and Ms. Sheilah Hendrickson, whose efforts, support, and assistance included the typing and editing of over 2500 pages of text.

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# ABSTRACT

The term "opportunity poison" refers to any substance that in military situations might be intentionally added to field water to deny its use; it implies that such contamination will be introduced as a spontaneous action, rather than as part of a preconceived plan. Thus, there are many different substances in military inventories and the civilian marketplace that because of their availability and toxic or organoleptic properties (e.g., taste, odor, or appearance) can be considered potential opportunity poisons for field water. To identify these substances and indicate their relative importance from a military perspective, we present a categorization matrix in which classes of compounds are ranked according to their military significance as potential opportunity poisons. The categorization matrix was assembled by considering (1) the probable availability from military or civilian sources, (2) the possible water-related health or aesthetic effects, and (3) the potential impacts on water-treatment equipment of the principal constituents of each class of compounds. On the basis of this analysis, recommendations are made for U.S. military forces to meet the threat of opportunity poisons by instituting guidelines and training programs that will (1) alert field forces to situations likely to involve the use of opportunity poisons and (2) define appropriate procedures for dealing with such situations. Quantifying the effects of the most important opportunity poisons (e.g., petroleum products) on field-water treatment equipment, particularly the reverse osmosis water purification unit (ROWPU), also is advised so that contingency plans can be made for operating and maintaining the equipment in the presence of such opportunity poisons.

# INTRODUCTION

Deliberate contamination of water supplies can effectively deny a water source to a military force. Contaminants can be lethal poisons or substances that impart adverse organoleptic characteristics (i.e., turbidity, color, odor, or taste) to a potential source of field water. Such purposely introduced contaminants may also affect the efficiency of water-treatment equipment. Those contaminating substances that are available in military inventories and the civilian marketplace and that can be easily introduced into water supplies without special equipment or prior training represent potential opportunity poisons.

Although opportunity poisons are substances that may be used either overtly (i.e., military forces of the U.S. and its allies suspect its use) or covertly (i.e., military forces of the U.S. and its allies do not suspect its use) in a tactical manner to deny water, the word "opportunity" implies an extemporaneous action. Therefore, the concept involving opportunity poisons is not classic, planned sabotage, but a more immediate, spontaneous action.

As previously mentioned, the substances considered to be opportunity poisons include those that induce sickness; make water unpalatable (i.e., produce objectionable taste, odor, color, or turbidity); or severely reduce the effectiveness of water-purification equipment. Substances producing organoleptic effects include a variety of readily obtainable chemical products, such as fuels, solvents, pesticides, and drugs. Nuclear, biological, or chemical (NBC) threat agents are not considered to be opportunity poisons because (1) generally they are not readily available from military inventories, (2) their utilization most likely will be part of a preconceived tactical plan, and (3) their application usually requires trained personnel and special equipment.

There have been very few documented cases of deliberate contamination of water supplies in a military theater of operation. However, at least four cases were investigated in South Vietnam in the 1960's. According to the personal experience of Kenison[1] two incidents involved deliberate contamination of water supplies that were being processed by an ERDLator water-purification device. In one case empty bottles that were found near-by contained residues of the pesticide endrin. In the second case the fish in the water source were found dead at the surface and a pesticide was suspected as the opportunity poison as this water source also was being processed by an ERDLator. Kenison[1] noted that in two other instances small water-treatment facilities being operated by civilian contractors were purposely contaminated. The substance was never identified but the automatic detection system at these two facilities registered

erratic changes in the pH of the water they were processing, and at one facility a bag was found that appeared to be designed to break up as it entered the plant intake so that it could release its contents. A more recent incident took place on the island nation of Grenada in 1983 just after U.S. military operations were completed. According to Phull,[2] it was reported that an individual attempted to contaminate a drinking water reservoir on the island by dumping a pesticide or herbicide into it.

The prospect of opportunity poisons being used to deny water to military forces would appear to be even greater today than in the past. With increased activity by international terrorist groups and dissident political groups, it is reasonable to assume that opportunity poisons may be included as a contingency plan in the operational doctrines of such groups.

The objective of this study is to identify and indicate the relative importance from a military perspective of the opportunity poisons that could be used to deny water to U.S. field forces. As part of our investigation, we compiled a bibliography identifying the publications that contain information about the use of opportunity poisons for denying field-water supplies to U.S. military personnel (see Appendix A). We also conducted interviews with (1) civilian and military personnel familiar with the production, storage, and distribution of field water and (2) people in the intelligence community knowledgable about foreign science and technology (see Appendix B). Thus we hoped to obtain the most recent consensus as to the opportunity poisons of most concern from the perspective of denying field water to military personnel. We reviewed the information obtained from the literature, and from our interviews identified the candidate classes of compounds considered to be suitable opportunity poisons for field-water supplies and predicted reasonably feasible scenarios for their use. Our assessment of the availability of the classes of compounds from military and civilian sources; the toxic and organoleptic properties of the principal constituents of each class of compounds; and the impact of each class of compounds on the effectiveness of water-treatment equipment led to the development of a categorization matrix in which the candidate classes of compounds are organized according to their relative importance from a military perspective.

## METHODOLOGY

The methodology for studying opportunity poisons began with a literature search of military documents. This search was conducted to identify candidate classes of potential opportunity poisons, their environmental fate and effects, and any previous use of these

substances as opportunity poisons against field troops of the U.S. and other nations. The literature search resulted in the retrieval of publications that provided an initial basis for this study. A bibliography of selected references is contained in Appendix A of this report.

To gather additional information about opportunity poisons, we interviewed people from many military organizations with an interest in field-water quality. These organizations included those responsible for operations, logistics, research, intelligence, and training. Within these organizations we selected interviewees with extensive background and experience in field-water supplies and treatment; the individuals and their organizations are listed in Appendix B. Significant information was obtained during this interview process.

## POTENTIAL SCENARIOS FOR USE OF OPPORTUNITY POISONS

The information that we obtained from our literature review and interviews confirmed our intuitive reasoning that field-water supplies can be intentionally contaminated in innumerable locations, from source to point of use, and in a variety of situations. Thus, it was necessary to reduce the possible combinations of locations and situations to a manageable number of scenarios. First we eliminated scenarios where the use of opportunity poisons would be impractical, such as attempts to deliberately contaminate very large bodies of field water. Generally, in such cases the quantity of an opportunity poison needed to adversely impact exposed military personnel or water-treatment equipment is considered prohibitive because of the effect of dilution or the fact that personnel and equipment can readily move to another shoreline area, away from the source of contamination. For example, the potential for a tactical force to deny water from an ocean, a Great Lake, or a swift-flowing river is very low, principally because of the comparatively small quantity (relative to the volume of water) of opportunity poisons quickly and easily available from military and civilian sources. Alternatively, opportunity poisoning of a groundwater well is a more probable scenario because the volume of water is far smaller and more isolated than that in large bodies of surface water.

To better define the maximum volume of natural water likely to be of concern to U.S. military forces in most situations from the perspective of opportunity poisoning, we calculated the amount of water that could be denied to field forces by the introduction of a readily obtainable quantity (55-gal drum) of the organic solvent, trichloroethylene (TCE), even in the presence of water-treatment equipment capable of removing up to 99% of the TCE from the source water. This solvent is representative of those widely

**Table 1. Water sources of minimal concern as targets for contamination by opportunity poisons.**

| |
|---|
| Oceans, bays, seas, and inlets |
| Large bodies of water with daily volumes exceeding $2 \times 10^6$ gal (e.g., large lakes)[a] |
| Large rivers and swift-flowing streams with flow rates exceeding 3.1 $ft^3/s$[b] |

[a] Volume calculated on the basis of diluting 55 gal of trichloroethylene (TCE) to a concentration equivalent to its odor-detection threshold (0.5 mg/L) in the effluent of water-treatment equipment capable of removing 99% of the TCE from the source water (see Appendix C).

[b] Flow rate corresponds to a daily volume of $2 \times 10^6$ gal (see Appendix C).

available opportunity poisons that produce adverse effects at low concentrations; the odor-detection threshold for TCE in water is 0.5 mg/L.[3] Our calculation (see Appendix C) reveals that natural waters with daily volumes up to $2 \times 10^6$ gallons and streams flowing at rates up to 3 $ft^3/s$ (the equivalent of a daily volume of $2 \times 10^6$ gallons) are suitable targets for effective contamination with opportunity poisons. Therefore, waters with volumes or flow rates greater than those just mentioned are of minimal concern (unless little or no water treatment was performed). Table 1 lists the water sources that are likely to be of minimal military concern as targets for contamination by opportunity poisons. In summary, these waters fall into this category because the amount of contaminant required would not be easily and quickly available. As mentioned previously, if a hostile force did manage to contaminate a very large water source, such as a lake or river, personnel responsible for water production could move the treatment equipment upstream to an uncontaminated area, or wait for dilution to occur.

Table 2 presents our assessment of the water sources of reasonable concern as targets for contamination by opportunity poisons in terms of the climatic regions defined by the U.S. Army in its Training and Doctrine Command (TRADOC) Pamphlet.[4] Our assessment revealed that lakes and rivers with daily volumes over $2 \times 10^6$ gal or flow rates exceeding 3 $ft^3/s$ generally are of minimal concern as targets for opportunity poisoning, particularly in temperate and tropical climates. However, in arid and arctic regions these waters could represent possible targets for deliberate contamination,

Table 2. Water sources of reasonable concern as targets for contamination by opportunity poisons.[a]

| Water source | Climatic regions: Arid | Arctic | Temperate | Tropic |
|---|---|---|---|---|
| Wells | X | X | X | X |
| Ponds | X | O | X | X |
| Lakes >2 x $10^6$-gal/d capacity | X | X (below frost line) | O | O |
| Rivers >3-$ft^3$/s flow rate | X | X (below frost line) | O | O |
| Streams | O | X | X | X |
| Irrigation canals | X | O | X | X |
| Municipal systems (reservoirs) | X | X | X | X |
| Military tactical water-storage tanks and distribution systems | X | X | X | X |

[a] X = opportunity poisons are of probable concern for corresponding water source.
O = opportunity poisons are of minimal concern for corresponding water source.

primarily because there is only a limited number of field-water sources available in these regions, and therefore the choice of targets is also limited. Streams in arid regions, and ponds and irrigation canals in arctic climates are of minimal concern as targets because of their low probability of occurrence.

Generally, the sources of field water most susceptible to deliberate contamination by opportunity poisons are (1) groundwater wells, (2) surface ponds, and (3) small lakes and municipal reservoirs. Furthermore, as indicated in Table 2, the water-storage tanks and water-distribution systems of military forces are also targets for contamination by opportunity poisons. In fact, water-storage tanks and distribution systems are excellent choices for opportunity poisoning because relatively small quantities of easily obtainable substances can contaminate the comparatively small volume of water in a storage tank or distribution system and deny its use. For example, foreign substances such as oil, gasoline,

and a variety of commercial chemicals (e.g., solvents) can be introduced into water-tank trucks and trailers. Even hose-line distribution systems, such as the Tactical Water Distribution System (TWDS), can be contaminated by opportunity poisons. A syringe might be used to inject hallucinogenic drugs (e.g., LSD or PCP) into such systems, and these drugs could have a devastating effect on military units exposed to this water. Furthermore, it would be difficult to detect such contamination before the occurrence of adverse health effects.

## PROBABLE OPPORTUNITY POISONS

As with the broad range of water sources representing potential targets for opportunity poisoning, the wide spectrum of compounds available to field troops for use as opportunity poisons required a selection process so that a manageable number of compound classes could be attained. First, four categories of opportunity poisons for water supplies were established: Category I – substances that potential enemy nations have in their military inventories that are analogous to substances in the U.S. Army inventory; Category II – substances that potential enemy nations have in their military inventories that are not analogous to any substances in the U.S. Army inventory; Category III – substances that are not general-issue items, but are provided to specialized military units; and Category IV – substances that can be obtained easily by military forces from civilian sources.

Next, we developed a list of the classes of compounds that might be used as opportunity poisons and divided the principal constituents of each class into the four categories as applicable. The list of classes of compounds was derived from information in the literature that we reviewed, interviews, and a U.S. Army Master Data File of inventoried stock items.

Table 3 presents a categorization matrix of the classes of compounds and their principal constituents. The relative ranking in Table 3 of each class of compounds is based on consideration of probable availability from military and civilian sources of the principal constituents, their possible water-related health or aesthetic effects, and their impacts on water-treatment equipment. Because opportunity poisons are not truly sabotage agents or NBC agents, few compounds are identified in Category III. Furthermore, the potential adverse effect of each class of compounds on health, aesthetics, or water-treatment equipment is indicated. The major classes of compounds are summarized in Table 4, ranked in descending order of availability and potential effects.

Table 3. Categorization matrix: opportunity poisons to deny a water source to military personnel.

| Relative ranking[a] | Class of compounds | Category of compounds[b] I | II | III | IV | Health or aesthetic effect | Impact on ROWPU[c] |
|---|---|---|---|---|---|---|---|
| 1. | Petroleum products and additives: | | | | | | |
| | Fuels and oils | Motor gas, diesel fuel, kerosene, aviation fuel transmission fluid | Tetraethyl lead, tetramethyl lead, ethylene dibromide | | Motor gas, diesel fuel, kerosene, aviation fuel transmission fluid | X | X |
| | Greases | Phospholipids, colloids | | | | | X |
| | Hydraulic fluids | | | | PCB | X | X |
| 2. | Solvents | Thinners, trichloroethylene, methylene chloride, phenols | Carbon tetrachloride, dry-cleaning agents (trichloroethylene) | | Carbon tetrachloride | X | X |
| 3. | Coolants | Ethylene glycol | | | Electrical equipment containing PCB's | X | |
| 4. | Insecticides, rodenticides, and repellents | Diazinon, lindane, strychnine, warfarin, ethylene dibromide, kerosene | Methyl bromide, DDT, sodium fluoroacetate | | Carbaryl, malathion | X | X |

Table 3. (Continued)

| Relative ranking[a] | Class of compounds | Category of compounds[b] | | | | Health or aesthetic effect | Impact on ROWPU[c] |
|---|---|---|---|---|---|---|---|
| | | I | II | III | IV | | |
| 5. | Herbicides and defoliants (not warfare agents) | 2,4-D, 2,4,5-T | Dioxin | | Dioxin, etc. | X | X |
| 6. | Water-treatment chemicals (including water test-kit chemicals) | Ferric chloride, formaldehyde, alum, chlorine, polyelectrolytes | | | Sodium fluoride, silver | X | X |
| 7. | Munitions, propellants, and thickeners | TNT, thickener, ammonium nitrate, nitroglycerin, mercury fulminate | Liquid propellants (with amines), isopropyl nitrite, hydrazine | | | X | X |
| 8. | Pyrotechnics, obscurants, and smokes | Smoke grenades, white phosphorus, and titanium tetrachloride | | | | X | |
| 9. | Detergents | Laundry, kitchen degreasers | | | Soaps, etc. | X | X |
| 10. | NBC decontamination compounds | STB, DS-2, BPL, caustics | | | | X | X |

Table 3. (Continued)

| Relative ranking[a] | Class of compounds | Category of compounds[b] I | II | III | IV | Health or aesthetic effect | Impact on ROWPU[c] |
|---|---|---|---|---|---|---|---|
| 11. | Fire retardants | Aqueous film-forming foam (AFFF) (glycols, surfactants, fluorocarbons) | | | Methyl bromide (fire extinguisher) | X | X |
| 12. | Riot-control agents | Tear gas, CS, chloropicrin | | | | X | X |
| 13. | Paints, coatings, and antifoulants | Antifouling paints and coatings | | | Antifouling paints and coatings | X | X |
| 14. | Dyes | Smoke grenades | Laundering substances (Soviets) | | | | X |
| 15. | Pharmaceuticals and disinfectants | Betadine, ammonia, Merthiolate | Iodine | LSD, PCP ("angel dust") | Sulfur, sulfates, laxatives, LSD, indole, skatole | X | X |
| 16. | Preservatives (mainly for construction materials) | Creosote, tar, sealants, pentachlorophenol, dimethoxane | | | Antifouling paints and coatings | X | X |
| 17. | Construction materials | Adhesives (resins, solvents), caulking compound, antidust agents | | | Adhesives (resins), sealants, asbestos products, paints | X | X |

Table 3. (Continued)

| Relative ranking[a] | Class of compounds | Category of compounds[b] | | | | Health or aesthetic effect | Impact on ROWPU[c] |
|---|---|---|---|---|---|---|---|
| | | I | II | III | IV | | |
| 18. | Spoiled food and food supplies | Springers[d] | | | | X | X |
| 19. | Dead and decaying organic materials | | | | Discarded corpse and composting material | X | |
| 20. | Industrial gases and chemicals | Acetylene, ammonia, various industrial chemicals | | | Industrial chemicals | X | X |

[a] Based on probable availability and consideration of possible water-related health effects and impacts on water-treatment equipment by the principal constituents of each class of compounds.

[b] The categories are defined as follows: I - substances that adversary nations have in the inventory of their armed forces that are analogous to substances in the U.S. Army inventory; II - substances that adversary nations have in the inventory of their armed forces that are <u>not</u> analogous to substances in the U.S. Army inventory; III - substances that are not general inventory items, but are organic to specialized military units; and IV - substances that can be easily obtained by adversary forces from civilian sources.

[c] ROWPU = reverse osmosis water purification unit.

[d] Military jargon describing poorly sealed food stuffs, particularly vacuum-sealed canned goods which have been contaminated by microorganims.

Table 4. Classes of potential opportunity poisons, listed in descending order[a] according to probable availability, possible water-related health or aesthetic effects, and impacts on water-treatment equipment.

| |
|---|
| Petroleum products |
| Solvents |
| Coolants |
| Insecticides, rodenticides, and repellents |
| Herbicides and defoliants |
| Water-treatment chemicals |
| Munitions, propellants, and thickeners |
| Pyrotechnics, obscurants, and smokes |
| Detergents |
| NBC decontamination compounds |
| Fire retardants |
| Riot-control agents |
| Paints, coatings, and antifoulants |
| Dyes |
| Pharmaceuticals and disinfectants |
| Preservatives (mainly for construction materials) |
| Construction materials |
| Spoiled food and food supplies |
| Dead and decaying organic materials |
| Industrial gases and chemicals |

[a] Descending order corresponds to decreasing order of relative importance in terms of military significance as potential opportunity poisons (see relative ranking in Table 4).

Table 5 contains potential opportunity poisons commonly encountered in military settings and available in the inventory of a military field force. In the table potential poisons are listed by type of compound and the chemical content of each type of compound is summarized. Tables 6 and 7 present the effects of incendiaries and screening smokes, respectively, when introduced into a field-water supply. The toxic effect of some of these compounds is small, but the physical effect (e.g., adverse appearance, odor, or taste) can be great, thus potentially inhibiting the production of potable, palatable water. Table 8 lists examples of acutely toxic chemical and biological substances that could be obtained from civilian sources, especially industrial and medical manufacturing and research facilities, and used as opportunity poisons for field-water supplies.

## DEFENSE AGAINST OPPORTUNITY POISONS

Protection against the use of opportunity poisons in water-supply systems is very difficult. Nevertheless, certain measures should be taken to defend against their use and/or mitigate their effects. The primary defense against opportunity poisons is to

Table 5. Available, commonly encountered potential opportunity poisons.[5]

| Potential opportunity poisons | Chemical content |
|---|---|
| **Acids** | |
| Pickling liquor<br>Battery acid<br>Acidic chemical cleaners<br>Spent acid | Chromic-sulfuric acid mixture, hydrobromic acid, hydrochloric acid, hydrofluoric acid, nitric acid, perchloric acid, sulfuric acid |
| **Alkalies** | |
| Miscellaneous caustic products<br>Alkaline battery fluid<br>Caustic wastewater<br>Cleaning solutions<br>Lye | Ammonia, lime (calcium oxide), potassium hydroxide, sodium hydroxide, sodium silicate |
| **Nonhalogenated organics** | |
| Capacitor fluids<br>Chemical cleaners and solvents<br>Chemical-toilet wastes<br>Laboratory chemicals<br>Paint removers | Aromatic compounds, organic amides, mercaptans, organonitriles, nitrobenzene, phosgene, thioureas |
| **Halogenated organics** | |
| Cleaning solvents<br>Laboratory chemicals<br>Paint and varnish removers<br>Capacitors and transformers containing PCB's<br>Mildew agents | Carbon tetrachloride, chloroform, methylene chloride, polychlorinated biphenyls, zinc naphthenate, copper naphthenate, dichlorophen |
| **Inorganics** | |
| Catalysts<br>Laboratory chemical wastes<br>Paint sludge<br>Plating solutions<br>Paints<br>Fluxes<br>Aluminum cleaning agents<br>Obscurants | Aluminum chloride, ammonium fluoride, ammonium silicofluoride, antimony salts, arsenic salts, asbestos products and fibers, beryllium compounds, barium salts, cadmium salts, chromium salts, cyanide compounds, inorganic halides (KBr, NaI), lead compounds, mercury salts, selenium salts, sodium silicofluoride, vanadium compounds, zinc chloride |
| **Explosives** | |
| Illegal explosives<br>Laboratory wastes<br>Obsolete explosives<br>Track torpedoes<br>Blasting caps<br>Detonators<br>Rocket fuel | Aluminum, ammonium nitrate, ammonium nitrate/fuel oil mixtures (ANFO), dynamite, ethylene glycol monomethyl ether, hydrazine, mercury fulminate, nitroglycerin, titanium compounds, TNT, water-gel explosives |

Table 5. (Continued)

| Potential opportunity poisons | Chemical content |
|---|---|
| Gases | |
| Welding gases<br>Laboratory gas cylinders | Acetylene, ammonia, carbon monoxide, chlorine, ethyl chloride, hydrogen, hydrogen sulfide, oxygen, and other gases under high pressure |

Table 6. Effects of incendiaries on water supplies.[6]

| Characteristics in water | Agent | | | |
|---|---|---|---|---|
| | Crude oil | Magnesium | Thermite | White phosphorus |
| Solubility | Insoluble | Insoluble | Insoluble | Insoluble, but soluble as oxide |
| Physical | | | | |
| Turbidity | Present | Present | Present | Present |
| Color | Brownish | None | Present | None |
| Taste, odor | Oily | Acid | Acid | Acid |
| Physiological | Production of toxic water very unlikely (presence of insoluble elemental phosphorus is a possible exception). Water likely to be nonpotable due to physical characteristics. | | | |

remain alert to clandestine contamination of water sources, storage tanks, and distribution systems. In particular, military personnel directly trained in the treatment, distribution, and storage of water should be cautioned about using or processing water with an abnormal appearance, odor, or taste.

Whenever possible, water sources used by U.S. forces should be located in protected areas. In fact, where water sources are extremely limited (e.g., in desert regions), tight physical security should be maintained at all times. Likewise, water distribution and storage equipment should be under close military protection when not in use.

Table 7. Effects of screening smokes on water supplies.[6]

| Characteristics in water | Agent: FS mixture[a] | Titanium tetrachloride | HC mixture[b] | White phosphorus |
|---|---|---|---|---|
| Solubility | Very soluble | Insoluble, forms the hydroxide | Some constituents | Insoluble, but soluble as oxide |
| Physical | | | | |
| Turbidity | None | Present | Present | Present |
| Color | None | None | Slight, black | None |
| Taste, odor | Very acid | Acid | Slight, metallic | Very acid |
| Physiological | Production of toxic water very unlikely (presence of insoluble elemental phosphorus is a possible exception). Water likely to be nonpotable due to physical characteristics. | | | |

[a] FS mixture = sulfur trioxide in chlorosulfonic acid.

[b] HC mixture = hexachloroethane - zinc oxide mixture.

Table 8. Examples of acutely toxic chemical and biological compounds that could be obtained from civilian sources (e.g., industrial and medical manufacturing and research facilities) and used as opportunity poisons for field-water supplies.

| |
|---|
| LSD |
| Staphylococcus enterotoxin |
| Arsenic |
| Cyanide |
| Fluoride |
| Sodium fluoroacetate |

An awareness of opportunity poisons, not necessarily concern about specific compounds, should be common to the field soldier and to specialists involved in the production, storage, and distribution of potable water. The first line of defense is the water-point operator, who should understand the concept of opportunity poisons and be prepared to deal with them in a responsible manner. In general terms, the response to opportunity poisons by responsible field personnel should occur in the following sequence:

- Suspect water contamination.
- Halt water-treatment and supply operations.
- Notify command.
- Conduct local checks.
- Take immediate corrective action, if possible.
- Notify medical personnel.
- Conduct medical evaluation.
- Locate a new water source.

Figure 1 is a simplified decision tree for dealing with contamination of a water source by an opportunity poison. Its inclusion in field manuals (e.g., TB MED 577)[7] and water-purification technical manuals is recommended.

Furthermore, training guidelines and exercises must be prepared and conducted for U.S. military forces to effectively handle opportunity-poison situations. Within the spectrum of tactical and troop-support responsibility, Engineer, Quartermaster, and Medical Corps commanders and personnel have the most immediate need for intensive training. These personnel have specific tasks in water procurement and distribution. Engineers are responsible for reconnoitering and reporting water sources. Quartermaster personnel are charged with equipment setup and production, storage, and distribution of potable water. Medical personnel are responsible for quality control and assurance of potable water. Their evaluations are critical in command decisions regarding the ultimate use of a water source because commanders must make the final decision based on the tactical situation, available support functions, and troop health and welfare.

Each of these groups requires training on the concepts and mechanisms of opportunity poisons. Of the four groups identified, we believe that quartermaster and medical personnel require the most intensive training. Quartermaster personnel must operate the equipment to produce the potable water, while medical personnel must know how to appropriately evaluate a contaminated water source. Medical personnel must decide whether contaminated water can be treated with the available equipment to

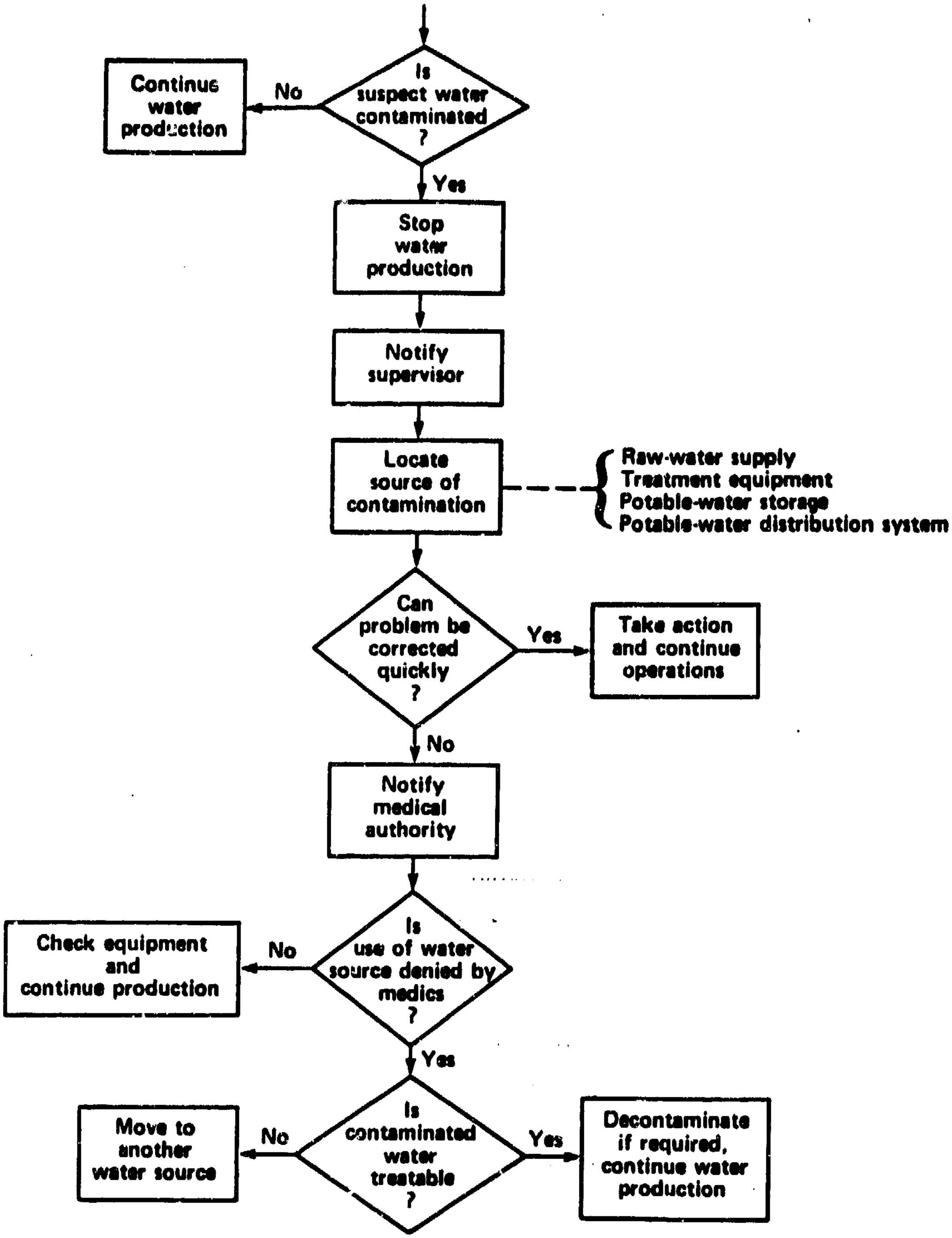


Figure 1. Decision tree describing recommended response sequence for military personnel to follow if opportunity poisons are suspected to be present in field water.

produce potable water of acceptable quality and quantity. Therefore, they must recognize the potential health impact of the contaminant, as well as its potential impact on the water-purification equipment.

Certain basic principles should be incorporated in the training programs to make key personnel aware of the contamination process and of its impact on water supplies.

At the level of water-treatment specialists (Quartermaster Corps), the training should stress the concept of opportunity poisons to make the operator aware of potential, intentional contamination of the source or treated waters. Operators should become aware of odor, taste, color, and changes in routine chemical test results, as indications of water contamination. Emphasis should be placed on development of accurate identification skills and immediate, appropriate responses to suspected contamination.

At the medical surveillance level (i.e., preventive-medicine technician, sanitary engineer, environmental science officer, and surgeon), the training emphasis should be twofold. First, the training should stress an awareness of potential situations involving opportunity poisons and indications of possible contamination. The geographic theater of operations and the nature of the enemy force are critical in evaluating opportunity-poisoning situations. Secondly, the training should enhance the capability of personnel to evaluate a contaminant's impact on troops and equipment. This involves identification of the class of compound, and quantification of the impact of that compound. Factors such as water-use requirements, water-source type and volume, and water-treatment equipment efficiency should be examined closely to quantify the impact of contamination with the compound.

One method to introduce training about opportunity poisons and their impacts (i.e., at the service-school level) is to develop selected scenarios in which the student must identify, quantify, evaluate, and make recommendations concerning use of a water source contaminated by an opportunity poison.

## SUMMARY

This report shows that there is an ample number of commonly available substances with the potential for quick and easy use by an enemy to deny utilization of a field-water supply. The most important of these substances from the perspective of use as opportunity poisons are petroleum products and solvents because they are readily available and possess both toxic and organoleptic properties. The report also shows that the water sources most threatened by opportunity poisons are small bodies of surface water, wells, cisterns, storage tanks, tactical pipelines, and/or distribution systems. The training of commanders, specialists, and troops to be aware of potential water

contamination with opportunity poisons is the best defense against the problem. By being cognizant of the threat and situations where a threat is most likely to occur, and the substances most likely to be used, a military field force may protect itself and its water supply, one of its most important resources.

## RECOMMENDATIONS

The following are our recommendations to meet the threat of opportunity poisons:

- Develop and distribute guidelines for use by U.S. military field forces on the threat of opportunity poisons. Technical bulletins, training manuals, and field manuals are appropriate publications for this information.
- Develop and implement in existing training programs for U.S. Engineer, Quartermaster, and Medical Corps personnel and troop commanders appropriate literature, practical exercises, and detailed training scenarios for opportunity poisons and appropriate responses.
- Conduct research quantifying the effects of the various identified classes of opportunity poisons on military water-treatment equipment, particularly the reverse osmosis water-purification unit (ROWPU). The suggested priority for further research is to examine the potential impacts of (1) petroleum products, (2) solvents, (3) coolants, (4) insecticides, rodenticides, and repellents, and (5) herbicides and defoliants, as possible opportunity poisons.

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# APPENDIX A
# BIBLIOGRAPHY

This bibliography is a compilation of military and other publications containing information about the use of opportunity poisons to deny a water source to a military force in the field. Many of the publications deal with potential contaminants, water-purification equipment and their treatment/removal of various contaminants, and the types of water-purification equipment and supplies that a potential enemy force might take into the field. Technical reports are listed first, followed by military technical manuals, and finally, military field manuals.

This bibliography was compiled by Mary-Bert Carmer of V. J. Ciccone & Associates, Inc. (VJCA). The sources of these documents are the VJCA library, local military libraries, and other military agencies.

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# APPENDIX B

## MILITARY ORGANIZATIONS AND INDIVIDUALS CONTACTED

| | Organization | Individual(s) contacted |
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| 2. | U.S. Army Environmental Hygiene Agency<br>Aberdeen Proving Ground (Edgewood Area)<br>Edgewood, MD 21010 | Lt. Col. J. Stratta<br>Capt. W. Andrews<br>Capt. M. Dougherty<br>Mr. S. Kistner |
| 3. | U.S. Army Quartermaster School<br>Fort Lee, VA 23801 | Lt. Col. J. McIlrath<br>Mr. J. Marigliano |
| 4. | U.S. Army Belvoir Research and Development Center<br>Petroleum and Environmental Technology Division<br>Fort Belvoir, VA 22060 | Mr. G. Eskelund<br>Mr. D. Lindsten<br>Capt. R. Thompson |
| 5. | Uniformed Services University of Health Sciences<br>Bethesda, MD 20014 | Col. C. Kenison<br>Dr. L. Legters |
| 6. | 18th Airborne Corps and Fort Bragg MEDDAC<br>Fort Bragg, NC 28307 | Maj. M. Moore<br>Capt. J. Curtis<br>M. Sgt. J. Hooks<br>Sgt. R. Kerr |
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| 10. | U.S. Environmental Protection Agency<br>Office of Drinking Water<br>Washington, DC 20460 | Mr. F. Bell |
| 11. | U.S. Army Medical Research and Development Command<br>Fort Detrick, Frederick, MD 21701 | Dr. S. Schaub |
| 12. | U.S. Armed Forces Medical Intelligence Center<br>Fort Detrick, Frederick, MD 21701 | Dr. B. Erlich<br>Dr. S.Watson |
| 13. | U.S. Army Toxic and Hazardous Materials Agency<br>Aberdeen Proving Ground (Edgewood Area)<br>Edgewood, MD 21010 | Lt. Col. J. Soyak |

# APPENDIX C

## CALCULATION OF THE MAXIMUM VOLUME OF WATER MOST LIKELY TO BE OF MILITARY CONCERN FROM THE PERSPECTIVE OF OPPORTUNITY POISONING

There are some lakes and other bodies of water so large and some rivers and streams so swift flowing that they do not represent a reasonable target for opportunity poisons. To estimate the maximum volume of water that is most likely to be of reasonable concern to military personnel as a target for opportunity poisons, we examined the use of trichloroethylene (TCE) as an opportunity poison. This is a common solvent that produces adverse organoleptic effects at very low concentrations in water. It is also readily obtained in 55-gal drums. Thus, we chose to use TCE for our calculation because it is representative of the widely available opportunity poisons that at low concentrations can make field water aesthetically objectionable and thereby preclude its use; the odor-detection threshold for TCE is 0.5 mg/L.[1] For purposes of this estimate we assume 100% solubility, perfect mixing of the TCE in the source water, and the availability of water-treatment equipment capable of removing up to 99% of the TCE. Therefore, the volume of water contaminated by the introduction of 55 gal of TCE so that a concentration of 0.5 mg/L will be present in the water after treatment to remove 99% of the contaminant is estimated to be approximately $2 \times 10^6$ gal according to the following equation:

$$V = TCE \times D \times T \times \frac{1}{OTC}$$

where

V = volume of field water contaminated to a concentration equal to the organoleptic-threshold concentration for TCE (gal);

TCE = volume of TCE introduced into the field-water supply as an opportunity poison (55 gal);

D = density of TCE at 20°C ($1.47 \times 10^6$ mg/L);

T = fraction of TCE remaining in water after treatment (1 - 0.99); and

OTC = odor-threshold concentration for TCE (0.5 mg/L).

Thus, $2 \times 10^6$ gal is a gross approximation of the maximum size of field-water sources that are of possible concern as potential targets for opportunity poisons. Equivalently, we can calculate the flow rate corresponding to a daily volume of $2 \times 10^6$ gal as follows:

$$2{,}000{,}000\ \frac{\text{gal}}{\text{d}} \times \frac{\text{d}}{86{,}400\ \text{s}} \times \frac{\text{ft}^3}{7.5\ \text{gal}} = 3\ \frac{\text{ft}^3}{\text{s}}\ .$$

We recognize that these estimates are based on only one opportunity poison and an assumed level of treatment efficiency and have a large amount of uncertainty associated with them. However, we believe that given the available information, they are somewhat realistic and with further research the uncertainty can be reduced substantially.

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